Comparison of Visual Acuity, Contrast Sensitivity and Spherical Aberration after Implantation of Aspheric and Spheric Intraocular Lenses

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Abstract

***Purpose*:** To compare visual outcome of aspheric and spheric intraocular lenses (IOLs) implantation in patients with age-related cataract in terms of visual acuity (VA), contrast sensitivity (CS) and spherical aberration

***Methods*:** In this prospective randomized interventional study, 59 consecutive cases of senile cataract who had been admitted for cataract surgery to Farabi Eye Hospital, Tehran, Iran between June 2008 and July 2010 were recruited. Patients were randomly assigned to two treatment groups using computerized software; eyes were implanted with either a aspheric or spheric IOLs (Acrylic, Lens Tec Co, Tehran, Iran). Pre and postoperatively, patients underwent complete ocular examination and their uncorrected visual acuity (UCVA) and best corrected visual acuity (BCVA) were measured. Three months after the operation patients were visited to measure spherical aberration and CS.

***Results*:** Fifty-two patients with the mean age of 55.7±5.9 years (range, 45-73 years) remained for surgical interventions. Postoperative UCVA and BCVA did not show a significant difference between our two study groups (P=0.124 and 0.400, respectively). Spherical aberration after cataract surgery in pseudophakic situation and pupil diameter of 5 mm was significantly lower in eyes with aspheric IOLs compared to spherical ones (0.22±0.10 vs. 0.30±0.12 µ, respectively, P=0.03). CS in all frequencies was better in aspheric IOLs compared to the spheric ones and except to the frequency of 20 cpd this difference was statistically significant (P<0.05).

***Conclusion*:** Although both aspheric and spheric IOLs resulted into a favorable VA, aspheric IOLs lead to better visual performance through a lower spherical aberration and better CS and quality of vision. However intraindividualization of asphericity by individual IOL surface design may be the best future option.

***Keywords*:** Spherical Aberration, Contrast Sensitivity, Cataract Surgery, Aspheric Intraocular Lens, Spheric Intraocular Lens

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Introduction

Nowadays, with improvements in manufacturing new intraocular lenses (IOLs), patients' visual performance and quality of life has become the main goals after phacoemulsification.[1] In young people the negative spherical aberration (SA) of the lens may compensate the positive spherical aberration of the cornea,[2,3] which can lead to an acceptable total aberration. But, in older ages, positive shift of primary spherical aberration and decrease in optical quality of crystalline lens results in lower visual quality.[4-6]

Implanting conventional aspheric IOLs with positive spherical aberration, added to the positive spherical aberration of the cornea can reduced quality of vision.[7-10] Now aspheric IOLs with negative spherical aberration compensates the positive spherical aberration of the cornea. This effect can restore the cornea-lens balance in the young eyes and might improve contrast sensitivity (CS) and enhance patients' visual performance.[11-15] However there are different opinions whether decreased spherical aberration would lead to improvement in CS and visual quality or not. CS and wavefront test has been shown to be appropriate investigations for evaluating subjects' visual quality.[16,17] This study is designed to assess visual performance of aspheric and spherical IOLs through comparison of visual acuity (VA), CS and spherical aberration.

Methods

Study design, population, inclusion and exclusion criteria

In this prospective randomized interventional clinical trial, all consecutive cases of senile cataract who had been admitted to Farabi Eye Hospital, Tehran, Iran between June 2008 and July 2010 were recruited. Patients who met inclusion criteria of being healthy and without other ocular pathology were eligible for the study. Exclusion criteria were expected VA worse than $^{20}/_{30}$, pupil anomalies, previous ocular trauma or intraocular surgery, history of uveitis, and coexisting ocular disease such as glaucoma, optic atrophy, or ocular tumors. Those with complications during or after the surgery such as vitreous loss, uveitis, posterior capsule pacification, IOL pigmentation or cystoid macular edema (CME) were excluded from the study. An informed consent was obtained from the patients for all surgical and study protocol.

Intraocular lenses and study protocol

Specifics of implanted IOLs are summarized in Table 1. Patients who met the inclusion and exclusion criteria initially underwent a complete ocular examination, indirect fundoscopy, tonometry and their best corrected visual acuity (BCVA) and uncorrected visual acuity (UCVA) were measured.

Table 1. The characteristics of intraocular lenses

Characteristics	Spheric	Aspheric
Optic Size	5.75 mm	5.75 mm
Optic Type	Equal convex	Equal conic,Bi-aspheric
Length	12.00 mm	12.00 mm
Haptic style	Modified C	Modified C
Angulation	0 Degrees	0 Degrees
Construction	1 Piece	1 Piece
Positioning holes	0	0
Optic material	Acrylic (26% water content)	Acrylic (26% water content)
A constant	118.0	118.0
A/C depth	5.10 mm	5.10 mm
Spherical aberration	+	0

Patients were randomly assigned to two treatment groups using computerized software and eyes were implanted with either of aspheric or spheric IOLs.

All operations were performed by the same surgeon using posterior chamber phacoemulsification through a temporal-limbal corneal tunnel incision under topical anesthesia. In all patients, IOL was implanted in the capsular bag. The aspheric and spheric IOLs (Acrylic, Lens Tec Co, Tehran, Iran) were implanted through the un-widened 3 mm limbal incision. Postoperatively, patients received topical Chloramphenicol every 6 hrs and betamethasone every 2 hrs for one week. Based on the patients` condition betamethasone was tapered within one month.

After the operation, patients again underwent a complete ocular examination, indirect fundoscopy, tonometry and their BCVA and UCVA were measured.

Spherical aberration measurement and analysis

Three months postoperatively, spherical aberration measurement of the operated eye was performed by a Hartmann-Shack sensor (Zywave, Bausch & Lomb Inc.) at the pupil diameter of 5 mm. Whenever pupil diameter was less than 5 mm, phenylephrine hydrochloride [Neo-Synephrine 5%] or tropicamide 1% eye drops were applied to dilate the pupil, in case of non-hypertensive and hypertensive patients, respectively. In order to reduce cycloplegic effects and displacement of the lens, measurement was performed at the pupil diameter of 5 mm.

Contrast sensitivity measurement

CS was measured in mesopic situation using the Metrovision Moniteur Ophtalmologique "STATphot" program (Metrovision, Pérenchies, France). Patient`s refractory errors were corrected before measurement. Standardized lighting conditions were ensured by blocking daylight. In this test patient at the distance of 2 m from the monitor looked at vertical sinusoidal grating. Visual field equal to 10 degree horizontal and 7.5 degree vertical is stimulated and then patient is exposed to six different spatial frequencies (1, 2, 5, 10 and 20 cpd). At first, contrast was too low for each of these frequencies to be seen by patient and gradually increased to be visible for the patient and the set was registered at this point. Tests on CS were not recorded for the first time and were repeated for several times to ensure reproducibility of results. Finally the graph was recorded by the system as previously described.[18,19] The study protocol was approved by the Ethics Committee of Tehran University of Medical Sciences (TUMS).

Primary and secondary outcomes

Primary outcomes were spherical aberration and CS in eyes implanted with aspheric and spheric IOLs. Secondary outcomes were BCVA and UCVA after cataract surgery in eyes implanted with aspheric and spherica IOLs. VA measurement was performed using logarithm of the minimum angle of resolution acuity (logMAR) scale under photopic conditions (85 cd/m^2).

Statistical analysis

Results were reported as mean±standard deviation (SD) for quantitative variables and percentages for categorical variables. The groups were compared using the Student's t-test for continuous variables like refractive and visual performance outcomes (UCVA, BCVA, spherical aberration and CS values at each frequency) and the χ^2 test (or Fisher's exact test if required) for categorical variables. P-values of 0.05 or less were considered statistically significant. All the statistical analyses were performed using SPSS version 13 (SPSS Inc, Chicago, IL, USA) for Windows.

Results

In this prospective study 59 patients (59 eyes) were enrolled in the study. Five eyes with BCVA less than $^{20}/_{25}$ and two others with CME during study were excluded. Finally, fifty-two patients with the mean age of 55.7±5.9 years (range, 45-73 years) remained for surgical intervention who were equally divided in two groups with spherical and aspheric IOLs. Patients' characteristics in each group are summarized in Table 2.

Spherical aberration after cataract surgery in pseudophakic situation and pupil diameter of 5 mm was significantly lower in eyes with aspheric IOLs compared to spheric ones

(0.22±0.10 vs. 0.30±0.12 µ, respectively, P=0.03). Table 3 shows CS in eyes with aspheric and spheric IOLs in mesopic situation at spatial frequencies of 1, 2, 5, 10 and 20 cpd. In all frequencies CS was better in aspheric lenses compared to the spheric lenses and except to the frequency of 20 cpd this difference was statistically significant (all P-values<0.05).

Table 2. Patients characteristics in each group

Variables	Aspheric	Spheric	P
Gender (Male/Female)	17/9	14/12	0.397
Age (year)	55.54±4.97	55.80±6.84	0.920
Laterality (Right/Left)	11/15	14/12	0.405
IOL power	20.46±1.81	20.65±1.25	0.875
Postoperative UCVA (logMAR)	0.07±0.07	0.04±0.04	0.124
Postoperative BCVA (logMAR)	0.01±0.03	0.01±0.03	0.400

IOL: Intraocular lens, UCVA: Uncorrected visual acuity, BCVA: Best corrected visual acuity, logMAR: Logarithm of the minimum angle of resolution

Table 3. Contrast sensitivity in eyes with aspheric and spheric intraocular lenses in mesopic situation and spatial frequencies of 1, 2, 5, 10 and 20 cpd.

Variables	Aspheric	Spheric	P
CS at frequency of 1 cpd	18.67±2.15	17.38±2.53	0.010
CS at frequency of 2 cpd	21.10±2.54	19.50±2.83	0.006
CS at frequency of 5 cpd	19.23±4.00	17.02±3.63	0.011
CS at frequency of 10 cpd	12.69±3.71	10.40±3.88	0.030
CS at frequency of 20 cpd	5.77±3.55	4.61±4.12	0.115

CS: Contrast sensitivity

Discussion

During recent decades, concurrent to the implementation of aspheric IOL technology, various kinds of IOLs with different amounts of asphericity have been introduced in order to obtain the best possible quality of vision. Nowadays achieving a plano refraction and VA of $^{20}/_{20}$ is not the main goal after cataract surgery and most of the surgeons intend to increase quality of vision through decreasing spherical aberration and subsequently increase CS since spherical aberration is the only higher order aberration (HOA) which can be diminished by using aspheric IOLs. Favorable VA is not always synonymous with optimal visual performance, as some patients with acceptable VA still suffer from disturbed quality of vision. Postoperative UCVA and BCVA three months after the operation did not show a significant difference between the two study groups, while their visual performance was not the same.

Spherical aberration after cataract surgery in pseudophakic situation and pupil diameter of 5 mm was significantly lower in eyes with aspheric IOLs compared to spherical ones 0.22±0.10 vs. 0.30±0.12 µ, respectively, P=0.03. A host of studies have shown partially lower spherical aberration after implantation of aspheric IOLs compared to the conventional spherical IOLs.[20-24]

Kurz et al in a well-designed parallel cohort investigated visual performance of 52 eyes of 52 patients unilaterally implanted with the aspheric Acri-Smart 36A IOL compared with those of 25 eyes of 25 age-matched patients unilaterally implanted with the spheric Acri-Smart 46S IOL. They confirmed no clinically relevant postoperative difference in CS between aspheric and spheric microincision IOLs.[25] They found a negative spherical aberration which was significantly different between aspheric (median= -0.09 µ) and spheric (median= -0.29 µ) at the pupil diameter of 4.5 mm. The beneficial use of aspheric IOLs had been shown in younger patients with larger pupil diameter.[26] But in the study by Kurz et al, the median age of the studied subjects was 71 years, that is much higher than our population (55.5 years).

Mester et al in an intraindividually randomized study of 45 patients compared the Tecnis IOL with a biconvex IOL with spherical surfaces (SI-40 Allergan). They found that the Tecnis IOL significantly improved low-contrast VA and CS. They revealed that aspheric IOL through compensation of positive spherical aberration in older age can lead to a remarkable improvement in CS and VA.[14]

In a similar study design, Kasper et al randomly implanted aspheric (Tecnis Z9000, AMO) in one eye and spheric (Sensar AR40e, AMO) in the fellow eye of 20 patients. Although Z(4)(0) was significantly lower in the eyes with aspheric IOL, they found no significant difference between the two IOLs in low and high-contrast VA and CS.[24]

In our study, in all frequencies CS was better in aspheric lenses when compared to the spheric lenses and except to the frequency of 20 cpd this difference was statistically significant ($P<0.05$). In consistence with our findings, several clinical investigations confirmed the partial superiority of aspheric IOLs in CS compared to spheric ones.[12-15] Kershner RM et al in a prospective study comparing the Tecnis IOL with AcrySof SA60AT IOL and the AA4207VF foldable Silicone IOL (Staar Surgical) found a considerable improvement in functional acuity contrast testing, mostly in night vision and night vision with glare, despite no significant difference in BCVA between groups.[14] In contrast, there are also studies which have shown that decrease in spherical aberration had not changed CS. Su et al compared spheric (Acrysof) IOLs in one eye with aspheric (Tecnis) IOLs in the fellow eye. In their study in spite of significant lower spherical aberration in aspheric lenses, CS was not significantly different in mesopic and photopic situation between these two IOLs.[27]

Hence for the fact that in about 10% of population corneal spherical aberration may be zero or even negative, aspheric IOLs with more negative spherical aberration could not be always the best choice.[28] It is believed that aspheric IOLs with negative spherical aberration through tilt and decentration in bag can increase coma and trefoil while it seems that aspheric lenses with zero spherical aberration similar to spherical lenses would lead to lower amounts of such aberrations. Various studies have confirmed that decentration in aspheric IOLs lead to more amounts of coma compared to spheric IOLs.[29-31] Denoyer et al compared two aspheric IOLs with negative spherical aberration (Tecnis Z9000) and zero spherical aberration (Softport AO). They found a better CS in lens with zero spherical aberration in photopic situation and spatial frequencies of 7.5 and 15 cpd while in mesopic situation and spatial frequencies of 3.75, 7.5, 15 and 30 cpd lens with negative spherical aberration show more favorable outcomes.[32]

Various studies had assessed different kinds of IOLs with different underlying optical materials and refraction indices with various designs which can lead to observed variety in the amount of induced aberration.[33] Kasper et al used two different IOLs in two eyes (spheric hydrophobic acrylic and aspheric silicone IOLs).[8] We applied aspheric and spheric hydrophilic acrylic IOLs manufactured in the same company (Lenstec co.) in order to lessen the bias. Since CS during the operation was performed with pupil diameter of 5.5 mm, wavefront measurement also was performed at pupil with diamter of 5 mm.

Patients' individual characteristic and aspheric IOLs centration could also play significant role in achieving higher quality of vision.[32] Thus, an intra-individually randomized comparison between the eyes of one patient by implanting an aspheric IOL in one eye and a spheric IOL in the fellow eye, we can have a better assessment of IOLs. Since cataract may affect total spherical aberration, it was not measured preoperatively in our study; however in most of the cases wavefront measurement was not possible due to severe cataract. Because of inexistence of appropriate equipment corneal spherical aberration was not measured in this study. Measurement of corneal spherical aberration could facilitate choosing aspheric lenses with negative or zero spherical aberration for each individual. We did not assess centration of IOLs after the operation. Meanwhile, in this study spherical aberration was only measured in a pseudophakic situation and at the pupil diameter of 5 mm and CS was investigated in mesopic situation. Measuring spherical aberration and CS in different situations and with various pupil diameters can be applied in further investigations to obtain a much clearer view.

Conclusion

Although both aspheric and spheric IOLs produce satisfactory VA, aspheric IOLs lead to better quality of vision in younger subjects through increasing CS that is due to their lower spherical aberration. However, individualized design of IOL asphericity based on a patient's spherical aberration seems to be the best future option.

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